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When genesis shapes cluster life cycle?

Applying mixed method on a French cluster case study

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Abstract: Adding to the growing literature on cluster life cycle (CLC), this paper gives new insights focusing on the crucial stage of genesis. We argue that the process by which clusters came into existence matters by structuring its further development. We conceptualize this dynamic process through an evolutionary perspective - considering the relevance of history - enriched by the relational and institutional ones, giving the structuring role of interpersonal ties and institutions. To implement this comprehensive approach of CLC, data availability becomes a great challenge since historical and relational materials are needed. We suggest using an original mixed method we apply on a French cluster. Whereas our understanding of the preexisting stages of the cluster official birth is only based on qualitative data, its evolution is derived from quantitative approach interpreted by qualitative one. The CLC appears to be driven by historical features which make it able to adapt over time.

Keywords: Cluster life cycle, genesis, embeddedness, mixed method, cluster policy.

JEL Codes: O32, R12, R38

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1. Introduction

Interests for cluster have emerged from the observation that many industries tend to cluster over time and in space. A sizeable literature dedicated to case studies of successful regional clusters like the Silicon Valley (Saxenian, 1994) has therefore been developed. Porter (1998), by proposing a synthesis of the existing works, favored the diffusion of the cluster concept in international organisations and the development of cluster policies in many industrialized countries (OECD, 2006; Borrás and Tsagdis, 2008; Njos and Jakobsen, 2016). Researchers have recognized these last years that “the existence and structure of clusters can only be understood when studying their dynamics over time” (Boschma and Fornahl, 2011, p. 1295). Aware of the necessity to integrate a dynamic perspective, cluster life cycle (CLC) approaches emerged searching to better understand how clusters become clusters, how and why they grow or decline (Menzel *et al.*, 2010; Pike *et al.*, 2010; Hassink, 2016). Through the development of theoretical frameworks and the multiplication of case studies, this recent literature has shed light on various drivers of clusters development as technological cycles or the evolving role of competencies and human agents. Despite these advances, some authors recently regret that “the current theory is more focused on describing how a cluster is organized today rather than how a cluster emerged” (Motoyama, 2008, p. 353). This has led some scholars to focus on drivers of cluster genesis, that differ from those supporting its further development (Bresnahan *et al.*, 2001; Henn, 2008). Nevertheless, “more knowledge about how new clusters emerge and why cluster grows in particular place is needed” (Isaksen, 2016, p. 704).

We propose to participate to this literature through an in-depth CLC analysis since its genesis. First, we recommend a comprehensive understanding of the genesis period integrating the preexisting context (cognitive, institutional and social) in which actors involved in the nascent cluster are embedded. Second, we argue for a sequential perspective of the CLC to analyze the impact of the genesis period on the subsequent trajectory. The conceptual framework consistent

with our proposition is based on an evolutionary perspective - considering the relevance of history and path-dependency - and enriched by the relational and institutional ones, giving respectively the structuring role of interpersonal ties and institutions.

To operationalize this framework, data availability becomes a great challenge since historical and relational materials are needed: data about the genesis period is missing since “the emerging cluster is not actually a cluster” (Menzel and Fornhal, 2009, p. 225). The main studies have been indeed interested in what is measurable and therefore concentrate on the cluster output (mainly through innovation project consortia) that does not exist before a certain period of life. We use a mixed method analysis to collect the relevant data for the CLC analysis of one French cluster (established within the framework of the Competitiveness Cluster policy). More precisely, the methodological strategy used relies simultaneously on quantitative data about innovation projects labeled by the cluster from 2006 to 2011 and on qualitative materials based on a dozen semi-structured interviews with the cluster members and governance, and the two-years immersion of an author within the cluster.

The paper is organized as follows. In the next section, we propose a brief survey of the CLC literature to better position our objectives and the underlying conceptual framework. The third section introduces our methodological strategy, its relevance to meet our positioning, and our case study and data. The fourth section gives the main results before discussing them and putting forward some policy implications.

2. Literature review and conceptual proposition

2.1. Grasping clusters: from statics to dynamics

The literature about clusters has been initially developed during the 1980s in a Marshallian spirit (Marshall, 1890) since which time the existence of technological positive externalities has

been one of the main explanation of the spatial concentration of industrial companies (“industrial districts” (Beccattini, 1992), “innovative milieu” (Maillat, 1995), “technological districts” (Antonelli, 2000)). Porter’s work (1998) has then favored the popularization of the cluster concept defined as “geographic concentrations of interconnected companies, specialized suppliers, service providers, firms in related industries, and associated institutions (...) in particular fields that compete but also cooperate” (p. 197). Since then, literature has focused on why clusters exist, how they work, and how they can be supported by public policies (Porter, 2000; Rosenfeld, 2001). Later, several authors have highlighted that cluster theory remains possibly misleading in the absence of life cycle considerations and have underlined the need to understand how clusters emerge, and change over time (Feldman, 2001; Feldman *et al.*, 2005; Fornahl *et al.*, 2015; Trippi *et al.*, 2015).

The recent literature therefore reports “an increasing recognition that the existence and structure of clusters can only be understood when studying their dynamics over time” (Boschma and Fornahl, 2011, p. 1295). The CLC literature mostly differentiates between the emergence, growth and expansion, decline or transformation (Enright, 2003). Since then, CLC frameworks have been developed according to the authors’ theoretical backgrounds. A first strand of cluster dynamics conception, heavily inspired by early works on product life cycles (Vernon, 1966) and industry life cycles (Klepper, 1997), considers that the growth of clusters mainly depends on the stage of evolution in a specific industry or technology. It tends to predict technological change rather than explaining the origins of technologies resulting from cluster innovation (Audretsch and Feldman, 1996). A second strand in CLC literature focuses on dynamic changes, drawing inspirations from concepts such as path-dependency and lock-in related to the “evolutionary paradigm” (Frenken *et al.*, 2007; Boschma and Iammarino, 2009; Martin, 2010). A last strand in CLC literature, centered around the research work of Bathelt and Glückler (2003), Trippi *et al.* (2015) and Pike *et al.* (2016), highlights the role of social

structure, labor relations and capital accumulation. It reaffirms the crucial role of the context (*i.e.* “contingency”) and proposes a conceptual position close to the relational economic geography framework (Bathlet and Glückler, 2003; Boggs and Rantisi, 2003).

2.2.The overlook of the genesis period until recently

Among the CLC literature, few studies insist on the crucial stage of genesis, the earlier moment leading to cluster formation, *i.e.* before cluster becomes visible and observable as such (Feldman and Braunerhjelm, 2006; Ter Wal and Boschma, 2011; Li *et al.*, 2012; Tanner, 2014; Frenken *et al.*, 2015; Isaksen, 2016). This stage appears relevant considering that factors supporting a cluster genesis may differ from those supporting its ongoing growth (Bresnahan *et al.*, 2001; Henn, 2008). It appears all the more determining since it can have an impact on the further stages of the CLC. Considering the structuring role of history, authors generally agree that “cluster formation is a sequential process with an evolutionary logic” (Braunerhjelm and Feldman, 2006, p.3). The development of evolutionary concepts - such as path-dependency, lock-in, capabilities, etc. - in economic geography (Boschma and Lambooy, 1999; Boschma and Frenken, 2007)) appears particularly relevant. Based on this evolutionary framework, a group of authors has considered that the heterogeneity of growth patterns would be partly due to different initial conditions. Some authors pointed out the relevance of small events: local industries “can be traced back to some seemingly trivial historical accidents”, (Krugman, 1991, p.35) and thus clusters “start out in a particular location more or less by chance” (Maskell and Malmberg, 2007, p. 612). Others have emphasized macro or meso factors of emergence. Crespo (2011) for instance considered that “the changes of the cluster through time depend on the joint evolution of two dynamics that are mutually influenced: technological dynamics and regional dynamics”. In the same line, Aitziber *et al.* (2012) pointed out the importance of historical preconditions, factors endowment, knowledge and other “triggering factors” (local demand and

policies). Alongside these latter studies, “the important question of how cluster structures emerge has often been (...) viewed as a process that is “individualistic in nature” (Li *et al.* (2012, p. 129). Indeed, authors have increasingly insisted on the role of entrepreneurship and spinoff creation (Feldman, 2001; Feldman *et al.*, 2005; Klepper and Sleeper, 2005; Carlsson, 2006; Feldman and Francis, 2006; Boschma and Wengting 2007; Buenstorf and Klepper, 2009; Dahl *et al.*, 2010) as a mechanism facilitating the process of (high tech) cluster formation.

2.3. The need of analyzing soil and roots: where do trees come from and how they develop?

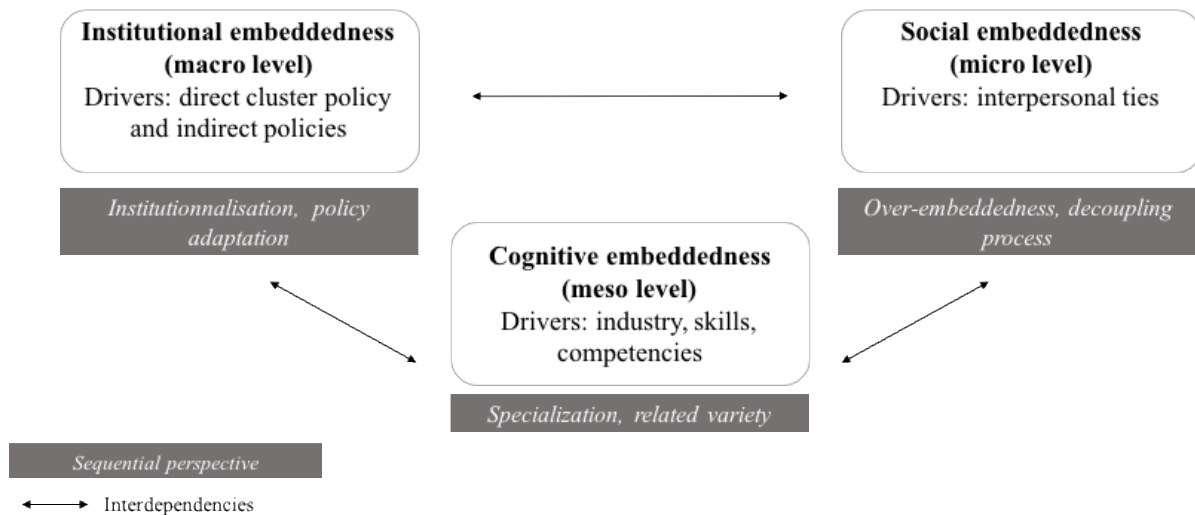
Focusing on the genesis period, our approach is fundamentally rooted in evolutionary approach considering history undoubtedly matters (David, 1985). We argue for a real dynamic framework through a sequential perspective: we give particular attention to the different time scales and to the burden of the past, to the previous decisions of actors that heavily determine their future choices. We therefore search to decrypt precisely clusters trajectory with possible bifurcation. Generally neglected, we consider that bifurcation constitutes an important step in which various directions become possible without being able to predict which one will be chosen (Wallerstein, 1997).

We also propose an in-depth and comprehensive approach, by integrating drivers at the micro, meso and macro-economic scales of analysis, a conceptual recommendation recently given by Trippi *et al.* (2015)². We therefore simultaneously pay attention to three types of embeddedness: social (*i.e.* the interpersonal ties of actors, operating at a micro-level), cognitive (*i.e.* the specific skills and technological domains, operating at a meso-level), and institutional (*i.e.* the policy framework, operating at a macro-level) contexts in which actors are situated. Finally, we

² “A stronger emphasis on the sensitivity and multiscalarity context of cluster evolution” is given since “cluster evolution results from the dynamic interplay between macro-, meso- and micro-factors” (Trippi *et al.*, 2015).

consider that these three scales of analysis and their corresponding drivers of CLC do not work in isolation but are interdependent in the genesis and evolution of clusters, as related in Figure 1. The conceptualization of such a multi-level approach is necessarily based on different theoretical approaches, as detailed in the following paragraphs.

Figure 1: Conceptual framework of CLC since genesis



Cognitive embeddedness: preexisting core competencies and cognitive evolution

We first consider the relevance of cognitive embeddedness of actors when analyzing genesis of cluster and its further evolution. Therefore, based on the evolutionary approach, we consider “the emergence of new local industry may not be due to chance or historical accident but stimulated and enabled (...) by preexisting resources, competences, skills, experiences inherited from previous economic activity” (Simmie and Martin, 2010, p. 79). This initial resources’ endowment is determining for the cluster formation and its further development through specialization, regional branching or technological relatedness (Tanner, 2011, 2014; Boschma and Gianelle, 2014; Boschma *et al.*, 2016). While history matters, “path dependency and resources accumulation are part but only part of the story” (Braunerhjelm and Feldman, 2006, p. 11). The Silicon Valley case suggests indeed that it is “the dynamic process of creating the

industry that created the concomitant location of the institution ingredients and the social relationships which makes them effective” (*ibidem*, p.1).

Social embeddedness: preexisting interpersonal ties and evolution of social network

New Economic Sociology has acknowledged the embeddedness of economic activities in a social structure: developed by Granovetter in a famous article published in 1985, social embeddedness refers to the idea that economic activities depend on interpersonal relationships in which the actors are involved. Thus, relying on a study by Eccles (1981), Granovetter shows that relations among companies (prime manufacturers and subcontractors in the construction field) are underlain by interpersonal relationships. Castilla *et al.* (2000) and Ferrary and Granovetter (2009) have shown the role of interpersonal ties between entrepreneurs (former PhDs) and researchers from the Stanford University on the emergence of the Silicon Valley. Similarly, Powell and Brantley (1992), Hagedoorn and Schakenrad (1994), Zucker *et al.* (1998), Powell *et al.* (1996), Almeida and Kogut (1997) emphasize the role of relationships of star scientists and firms in the concentration of R&D partnerships and the cluster of specific technology in the United States. This crucial role of social embeddedness for the clusters life cycle analysis has been also recently underlined by authors from the relational economic geography (cf. *supra*). Following this approach, we argue for the integration of social embeddedness as a driver of the cluster emergence and its further evolution. We do not only have to pay attention to the embeddedness process but also to the decoupling one (Granovetter, 1973), the process of empowerment from previous interpersonal ties to collective organizations while actors can suffer from over-embeddedness (Burt, 1992; Uzzi, 1999; Grossetti, 2008; Hagedoorn, 2008). The embeddedness theory as advanced by Granovetter was the subject of a certain number of criticisms: for example, Portes (1998) or Baret *et al.* (2006) highlighted the overestimation of the interpersonal relationships in the socio-economic activities. Social

embeddedness cannot be viewed in isolation, local actors can be at the same time embedded in macrostructures.

Institutional embeddedness: policy framework and policy adaptation

We need to appreciate the embeddedness of actors in preexisting institutional context. Following the institutional approach, we argue that cluster policies, designed at a national level to initiate regional specialization, can directly provide support to the formation process of cluster and to its changes. Indirect policies must be also taken into account: the previous creation of public structures such as technology and science parks, research universities (Belussi and Sedita, 2009; Paton and Kenney, 2010) can participate to the cluster creation in its early phase and provide reinforcement in the later phase (Carlsson, 2005; Prevezer, 2008; Flanagan *et al.*, 2011; Njos and Jakobsen, 2016; Uyarra and Ramlogan, 2017). We argue for a dynamic approach of how institutions shape clusters (Ingstrup and Damgaard, 2013). This dynamic perspective requires to consider the evolving rationales for cluster policies and the difficulty of policy implementation (Uyarra and Ramlogan, 2017).

3. Methodological proposition and data used

In this section, we first introduce our methodological strategy, the mixed method analysis, and its relevance to meet our goals and operationalize our conceptual framework. We then present our specific case study and the data used.

3.1. Benefits of the mixed method for cluster life cycle analysis

The recent development of empirical literature about CLC is based either on in-depth qualitative analysis (Giuliani and Bell, 2005, 2007; Morrison, 2008; Belussi and Sedita, 2009; Giuliani and Varza, 2009; Giuliani, 2011; Shin and Hassink, 2011; Giuliani and Pietrobelli, 2014; Hervas-

Oliver and Albors-Garrigos, 2014; Belussi and Hervas-Oliver, 2017; Hervas-Oliver *et al.*; 2017) or on social network analysis (Giuliani, 2007; Steiner and Ploder, 2008; Giuliani *et al.*, 2010; Balland *et al.*, 2013; Crespo *et al.*, 2016). Both methodologies give new insights regarding their own advantages and limits for the CLC analysis. Based on interviews, participatory approaches, case studies or focus groups, qualitative approaches are considered appropriate for process evaluation and contribute to enhancing information about the institutional environment and to deeply understanding the complexity of the formation process. They nevertheless rarely integrate longitudinal data and the various potential drivers of CLC (they are mostly focused on a specific one). The quantitative ones are relevant to describe how clusters evolve, although they suffer from a precise interpretation of the network evolution: they can identify actors who become more and more central in the network, but do not have any information to justify this centrality reinforcement. Moreover, they face the unavailability of data about the genesis period since “the emerging cluster is not actually a cluster” (Menzel and Fornhal, 2009, p. 225). The main studies have been indeed interested in what is measurable and therefore concentrate on the cluster output (mainly through innovation project consortia) that does not exist before a certain period of life (van der Linde, 2003; Feldman, 2005; Carlsson, 2005, 2006; Braunerhjelm and Feldman, 2006; Prevezer and Tang, 2006; Stoerring and Dalum, 2007; Ritvala and Kleymann, 2012; Isaksen, 2016).

Advantages and limits of quantitative and qualitative studies rely finally on data availability, one of the main challenges to develop a comprehensive analysis of CLC, in order to integrate the context in which local actors are embedded. Indeed, to reach this goal, we need both i) longitudinal data, sufficiently precise to decrypt the transition between the various stages and the subsequent impact of the initial drivers, and ii) relational data to establish the existing relationships between the various actors within the cluster and how they evolve over time (Giuliani, 2013). About longitudinal data, collecting information at the earliest possible stage

of cluster existence has necessarily to be done in a qualitative way as quantitative data do not exist as long as the cluster is not created. About relational data, Balland *et al.* (2013, p. 761) suggest not only implementing social network analysis based on consortium data, but also conducting “a more qualitative approach (...) that could deepen our understanding of the motives behind networking and the role of more informal personal ties”.

The combination of qualitative and quantitative approaches through mixed method (Box 1) appears therefore as a promising way for an in-depth analysis of CLC. Even recommended by Boschma and Fornhal (2011, p. 1297), the mobilization of “different data sources, ranging from the collection of primary data by qualitative research or questionnaires, to a multitude of secondary data sources” has been rarely used until now (except Giuliani and Varza (2009)).

Applied to CLC analysis, the implementation of a mixed method relies on the collection of existing quantitative data (consortia involved in innovation projects) combined with historical and qualitative data. More precisely, following Park and Kluver (2009), we propose first to carry out social network analysis on quantitative data to characterize the network properties at the various stages of the cluster life cycle, and then to complete the analysis with a qualitative approach in order to enter the black box of networks. We therefore give an interpretation of the statistical trends observed and decrypt the complex trajectory of the cluster. By reintroducing “the real-life experience, bibliographical events that leave traces, qualitative data give a different thickness and a better understanding of quantitative data” (De Federico de la Rúa and Comet, 2011, p. 9); they serve to take the context into account (Edwards, 2010), to bind content analysis of network structure (D’Angelo *et al.*, 2014) and to explore in depth the reasons for change (*ibidem*).

Box 1: Mixed method analysis

Initially used in the social sciences in the 1950s with a key article on psychology (Campbell and Fiske, 1959), the mixed method analysis was developed and spread to other human and social sciences in the 1980s. In comparison with sociology, educational science and political science, mixed methods have been less frequently used in economics (except for the evaluation of public policies) and economic geography.

Mixed methods are based on the variation in data collection and used for research that involves collecting, analyzing and integrating quantitative and qualitative data in a single study (Small, 2011). Basically, it is assumed that quantitative and qualitative approaches are not irreducible but complementary (Winter, 1984). These two approaches are combined to exploit the strengths of each: statistical and systemic results but misinterpretation risks on the quantitative side *versus* “decoding” of complex processes, behaviors, or trajectories but illustrative and contextual analysis on the qualitative side (Starr, 2012). The combination of qualitative and quantitative approaches can be done either through triangulation in order to obtain convergence and verification of the results via different data, or through the nesting of additional data to deal with different facets of the same subject.

3.2. The case study and the data used

The methodology proposed earlier is applied to Elopsys, a French Competitiveness Cluster (CC) (Box 2). This cluster is specialized in high technology sectors - microwaves, photonics, secure networks and digital interfaces - and is located in the French region of Limousin. This is a relatively small region, located in the center of the country. As indicated in Table 1, its scientific productivity is high compared to its rank in R&D expenditures and patent filing, with a higher level of dependency on public organizations than the average. Regional activity in the

cluster's domains accounts for 18% of regional industrial employment today: the Limousin regional development agency identified more than 70 businesses in this sector,³ employing more than 7,500 people encompassing all levels of qualification. This sector generates more than 25% of regional exports and is based on extensive public and private regional research. SMEs are over-represented in this cluster (Table 1).

Box 2: French competitiveness cluster policy

In 2005, the French government implemented a national cluster policy to create competitiveness clusters, defined as a “combination, in a given geographical area, of companies, training centers and public and private research units engaged in a partnership designed to create synergies around common innovative projects” (www.competitivite.gouv.fr). Seventy-one CCs were set up, each in a given area of France, around a specific sector (IT, electronics, biotechnology, wood industry and clean technology, notably). Recommendations were strengthened by a decree of May 2007 that defines R&D zoning and stipulates that “the presence of an enterprise within the zone entitles it to additional financing when it participates in collaborative projects approved by the cluster”. The territorial concentration of actors is thus strongly encouraged.

Firms, research centers and other organizations from each cluster propose collaborative projects that are launched in a two-step procedure. They are first labeled by the CC, before searching for funds from various sources: i) the National Research Agency, ii) the governmental fund dedicated to CC projects, iii) European funds, generally through European Framework Programs and the European Regional Development Fund; iv) local funds, mostly from local authorities (Regional Councils, public investment banks, etc.).

³ Aware of the opportunities offered by these companies in terms of local economic development, “the Limousin region voted in March 2005 for an initial authorization for programs for a sum of €5 million, supporting the Elopsys and Ceramic clusters”, according to the Head of Economic Development at the Limousin Regional administration.

Table 1: Positioning of Limousin and Elopsys vis-à-vis other French regions and CCs

	Limousin [ranking]	French average [excl. Ile-de-France]
Total R&D expenditure in 2009 (per inhabitant)	219.22 € (100%) [18 th /22]	650.67 € (100%) [472.81 € (100%)]
Private R&D expenditure in 2009 (per inhabitant)	132.49 € (60.4%) [18 th /22]	415.39 € (63.8%) [297.82 € (63%)]
Public R&D expenditure in 2009 (per inhabitant)	83.73 € (39.6%) [17 th /22]	235.29 € (36.2%) [174.99 € (37%)]
Number of patents filed in 2009 (per million inhabitants)	60.92 [21 st /22]	174.29 [143.95]
Number of scientific publications published in 2009 (per million inhabitants)	498.22 [11 th /22]	736.83 [612.50]
	Elopsys	Average of the 70 other French CCs
Companies involved (in 2012)		
Number of member companies	64	134
Including SMEs	52 (81.3%)	89 (66.3%)
Number of employees (including executives)	3 369 (435)	11 892 (4046)
Export performance (in 2012)		
Export rate of member companies	33%	24%
Export rate of member SMEs	40%	26%

Source: Eurolio dashboard (<http://sgbd.eurolio.eu/>) & DGCIS annual survey of clusters (<http://competitivite.gouv.fr/tableaux-de-bord-statistiques/les-tableaux-de-bord-statistiques-des-poles-1000.html>)

By the end of 2011, the cluster had acquired near 100 members and labeled 250 projects: comparing these figures with those of other French CCs (Table 1), the cluster studied is about average and constitutes a relevant setting to analyze collaborations within clusters.

We use quantitative data related to the projects labeled by the competitiveness cluster from 2005 to 2011. More precisely, using these consortium data, we build a database of 250 labelled

projects involving nearly 500 participants, 1,000 participations⁴ and 3,000 bilateral ties. Table 2 shows the quantitative data used according to the scale of analysis: projects, actors (participant/participation) and collaborations. Based on this data, we are able to provide descriptive statistics, to conduct a social network analysis and to reveal the structural properties of the cluster network for each year of the studied period.

When computing a network analysis, nodes correspond to participants and ties to dyadic relations between two partners involved in the same collaborative project. Projects are represented in one-mode networks and single-partner projects (33 cases of start-up creation) are not excluded from the analysis as we do not focus on collaboration processes but rather on cluster evolution: they represent isolated nodes until they participate in a collaborative project. To characterize the structural properties of the network and the position of actors, we use classical indicators such as average degree, density and centrality scores⁵. The network analysis is completed by a set of variables and indicators serving to describe the evolution of other cluster patterns: Are projects more and more co-labelled? Are partners more and more local? Are collaborations more and more conducted between science and industry? etc.

Table 2: Variables under study by scale of analysis

	Project n=250	Actors		Collaboration n=2866
		Participant n=471	Participation n=1140	
Co-labeling				
Size				
Technological domain				
Funds				
Renewal (new/former)				
Membership				
Geography				
Type of organization				

In gray, the studied variables by scale of analysis

⁴ One actor can participate to several projects, that lead to distinguish between participant and participation. On average over the studied period, actors participate to two projects.

⁵ We use Pajek software, which is commonly used for SNA.

For the qualitative approach, we collected data from two main sources:

1. Our immersion within cluster life for a two-year period (2012-2013) allowed us to attend some executive board meetings and steering committee meetings; we were thus able to collect qualitative data about cluster governance and history.
2. We conducted a first group of face-to-face semi-directed interviews with three successive managers of the cluster about the history of the cluster, its development and the key issues facing it. A second group of interviews was conducted with nine researchers involved in thirteen labeled projects. These interviews mainly focused on the role played by the cluster in the formation and implementation of the project. More precisely, for each collaboration studied, we focused on the origins of the collaboration in order to identify how the partners' networking was initiated and whether the CC itself or members had a role in this linkage.

4. Cluster genesis and impact on the subsequent trajectory of Elopsys

Based on the methodology proposed earlier, the combination of qualitative and quantitative materials has evidenced a three-step cluster life cycle analysis. The genesis period constitutes a crucial first step; the following stage appeared as following the initial trajectory whereas a bifurcation appeared in 2009 branching from the former steps. This sequential analysis is detailed in the next three subsections.

4.1. The genesis: a nascent specialization supported by policies and favored by preexisting relationships (before 2005)

We pay particular attention to the early moments of creation, the genesis of the cluster, which is unobservable quantitatively. The Limousin region displays a historical specialization in porcelain since the 18th century (Perrier, 1924; Le Bot, 2013), which invites naturally to apply

for a cluster in this sector. Despite this preexisting local knowledge, political opposition led to debate about the appropriateness of exclusively supporting this local industry, claiming “there is not only ceramics in Limousin”. Hyperfrequencies were indeed strongly represented locally given the specialization of an academic laboratory and some of the biggest local companies (Photonis, Thalès, Anovo, etc.). More precisely, Ircom - the academic laboratory - and Creape - a technology transfer center - played a major role in the local development of hyperfrequencies by collaborating heavily with academic entrepreneurs, hugely involved in applied research transferable to industry. This dynamic was encouraged by the existence in Limoges of a Technology Park (Ester technopole) since 1993. This park hosts cutting-edge skills, supports mechanisms and specialized services and provides a fertile environment for the economic development of Limousin. A researcher talked about its benefits in terms of innovation: “the unity of place and action is convenient; we are able to do experiments here”.

In 2004, a national call for competitiveness clusters was launched by the French government. Limousin, like other French regions, was encouraged to consider cluster projects. The Region thus commissioned a consultancy firm with a study about a cluster specialized in hyperfrequencies. A researcher from the University of Limoges was also seconded in his position to prepare the “cluster application form”. Therefore, the regional council decided to apply for a project based on this high-tech cluster.

Regarding the genesis period, we observe the crucial role of clusters policies, both local and national and also direct and indirect. Despite the local historical specialization, regional policy supported heavily the nascent high-tech capabilities of the region and bet on the emerging science-industry relationships, already favored by the technology park establishment. Cluster patterns (specialization, concentration and partnerships) has been reinforced heavily. The genesis period also highlights the interaction between the three levels of action: social embeddedness of actors, industrial specialization and institutional support.

The cluster development - analyzed through descriptive statistics (Table 3) and social network analysis (Table 4) of Elopsys projects, and qualitative materials - is then divided in two main stages we are going to detail in the next sub-sections.

Table 3: Descriptive statistics on projects, actors and collaborations

	Period	2006	2007	2008	2009	2010	2011	Total
Project	Total (cum.)	30 (30)	40 (70)	33 (103)	36 (139)	42 (181)	69 (250)	250
	Co-labelled projects (%)	2 (7)	6 (15)	4 (12)	8 (22)	5 (12)	33 (48)	58 (23)
	Size (%)							
	< 5	21 (70)	27 (68)	23 (70)	17 (47)	23 (55)	39 (57)	150 (60)
	≥ 5	9 (30)	13 (33)	10 (30)	19 (53)	19 (45)	30 (43)	100 (40)
	Mean of participant by project	3.8	3.8	4.2	4.5	5.1	4.9	4.5
	Technological domain (%)							
	Microwaves	13 (43)	22 (55)	19 (58)	16 (44)	21 (50)	32 (46)	123 (49)
	Photonics	14 (47)	9 (23)	7 (21)	14 (39)	7 (17)	20 (29)	71 (28)
	Secure networks	3 (10)	6 (15)	2 (6)	0 (0)	7 (17)	4 (6)	22 (9)
	Digital interfaces	0 (0)	3 (8)	4 (12)	4 (11)	7 (17)	10 (14)	28 (11)
	Transverse	0 (0)	0 (0)	1 (3)	2 (6)	0 (0)	3 (4)	6 (2)
	Funds (%)							
	Local	6 (20)	8 (20)	2 (6)	4 (11)	5 (12)	5 (7)	30 (12)
	CC policy	3 (10)	3 (8)	6 (18)	8 (22)	5 (12)	9 (13)	34 (14)
Research Agency	21 (70)	28 (70)	25 (76)	24 (67)	32 (76)	50 (72)	180 (72)	
Europe	0 (0)	1 (3)	0 (0)	0 (0)	0 (0)	5 (7)	6 (2)	
Participant	New (cum.)	77 (77)	61 (138)	48 (186)	56 (242)	88 (330)	141 (471)	471
	Member (%)	16 (21)	8 (13)	3 (6)	4 (7)	4 (5)	9 (6)	44
	Geography (%)							
	Local	19 (25)	13 (21)	4 (8)	6 (11)	9 (10)	15 (11)	66 (14)
	National	56 (73)	48 (79)	44 (92)	50 (89)	70 (80)	91 (64)	359 (76)
	International	2 (3)	0 (0)	0 (0)	0 (0)	9 (10)	35 (25)	46 (10)
	Type of organization (%)							
Science	48 (62)	24 (39)	27 (56)	26 (46)	41 (47)	57 (40)	223 (47)	
Industry	29 (38)	36 (59)	19 (40)	25 (45)	40 (45)	71 (51)	220 (47)	
Other	0 (0)	1 (2)	2 (4)	5 (9)	7 (8)	13 (9)	28 (6)	
Participation	Total (cum.)	115 (115)	150 (265)	137 (402)	163 (565)	214 (779)	341 (1120)	1120
	New (cum.)	77 (77)	61 (138)	48 (186)	56 (242)	88 (330)	141 (471)	471
	Former* (cum.)	38 (38)	89 (127)	89 (216)	107 (323)	126 (449)	200 (649)	649
	Renewal rate (%)	33	59	65	66	59	59	58
	Member (%)	47 (41)	50 (33)	46 (34)	51 (31)	49 (23)	104 (30)	347 (31)
	Geography (%)							
Local	50 (43)	56 (37)	46 (34)	51 (31)	52 (24)	95 (28)	350 (31)	

	National	63 (55)	94 (63)	91 (66)	112 (69)	152 (71)	210 (62)	722 (64)
	International	2 (2)	0 (0)	0 (0)	0 (0)	10 (5)	36 (11)	48 (4)
	Type of organization (%)							
	Science	73 (63)	84 (56)	81 (59)	97 (59)	132 (62)	194 (57)	661 (59)
	Industry	42 (37)	65 (43)	54 (39)	60 (37)	74 (34)	132 (39)	427 (38)
	Other	0 (0)	1 (1)	2 (2)	6 (4)	8 (4)	15 (4)	32 (3)
Collaboration	Total (cum.)	219 (219)	319 (538)	307 (845)	372 (1217)	588 (1805)	1061 (2866)	2866
	New (cum.)	206 (206)	242 (448)	234 (682)	255 (937)	467 (1404)	830 (2234)	2234
	Former* (cum.)	13 (13)	77 (90)	73 (163)	117 (280)	121 (401)	231 (632)	632
	Renewal rate (%)	6	24	24	31	21	22	22
	Membership (%)							
	Member-Member	30 (14)	19 (6)	19 (6)	23 (6)	8 (1)	52 (5)	151 (5)
	Member-Non member	89 (40)	107 (34)	123 (40)	139 (37)	180 (31)	358 (34)	996 (35)
	Non member-Non member	100 (46)	193 (60)	165 (54)	210 (57)	400 (68)	651 (61)	1719 (60)
	Geography (%)							
	Local-Local	37 (17)	30 (9)	19 (6)	35 (10)	18 (3)	61 (6)	200 (7)
	Local-National	86 (40)	110 (35)	121 (39)	109 (29)	153 (26)	241 (23)	820 (29)
	Local-International	2 (1)	0 (0)	0 (0)	0 (0)	18 (3)	59 (5)	79 (3)
	National-National	93 (42)	179 (56)	167 (55)	228 (61)	377 (64)	456 (43)	1500 (52)
	National-International	0 (0)	0 (0)	0 (0)	0 (0)	6 (1)	171 (16)	177 (6)
International-International	1 (0)	0 (0)	0 (0)	0 (0)	16 (3)	73 (7)	90 (3)	
Type of organization (%)								
Science-Science	86 (39)	104 (32)	93 (30)	125 (34)	188 (32)	247 (23)	843 (29)	
Industry-Industry	47 (22)	73 (23)	82 (27)	67 (18)	134 (23)	278 (26)	681 (24)	
Science-Industry	86 (39)	140 (44)	124 (40)	151 (40)	213 (36)	430 (41)	1144 (40)	
Other	0 (0)	2 (1)	8 (3)	29 (8)	53 (9)	106 (10)	198 (7)	

**If an actor participates in two projects during the same year, we consider that he is new the first time and former the second time, explaining how we can find former partners since the first year.*

***Renewal rate=former/total*

Table 4: Network analysis over time

		2006	2006-2007	2006-2008	2006-2009	2006-2010	2006-2011
Structural properties	Number of nodes	77	138	186	242	330	471
	Number of isolated nodes	4	10	11	10	14	22
	Number of ties	206	448	682	937	1404	2234

	Total number of components	3	1	1	2	1	1
	Size of the biggest component (%)	49 (63.6%)	128 (92.7%)	175 (94.1%)	227 (93.8%)	316 (95.8%)	449 (95.3%)
	Average degree	5.4	7.6	8.9	9.9	10.9	12.2
	Density	0.071	0.055	0.048	0.041	0.033	0.026
	Average distance*	2.5	3.0	2.9	2.9	3.0	2.9
	Diameter (max. geodesic distance)*	4	6	5	5	6	6
Degree centrality	Xlim-OSA						
	Cisteme						
	Xlim C2S2						
	Xlim-Minacom						
	Xlim-Photonique						
	CEA						
	France Telecom						
	Xlim-DMI						
	Alcatel-Thalès Lab.						
	Alcatel-Lucent						
	Xlim-SIC						
INRIA							
Closeness centrality	Xlim-OSA						
	Xlim-Minacom						
	Cisteme						
	INRIA						
	France Telecom						
	CEA						
	Thalès Com.						
	Xlim-Photonique						
	Xlim-SIC						
	Alcatel-Thalès Lab.						
	Xlim-C2S2						
	Radiall Systems						
	Telecom Bretagne						
	Supelec						
IETR							
Betweenness SS	Xlim-OSA						
	Xlim-Minacom						
	Xlim-Photonique						
	Xlim-C2S2						

	Xlim-DMI						
	CEA						
	Cisteme						
	France Telecom						
	INRIA						
	Xlim-SIC						
	ENST						
	Thalès Com.						

** in the biggest component*

We report in this table the actors which are among the top-ten central in at least two periods.

4.2.Reinforcement of the initial trajectory

Emergence of Elopsys: reinforcement of the technological specialization through interpersonal relationships (2005-2006)

The cluster was officially created on July 2005 and took the name “Elopsys”. A crucial restructuration of this scientific eco-system occurred thereafter. First, Creape, the former technology transfer center was restructured and merged to become bigger and officially recognized as a regional one through the appellation Cisteme (Center for Telecommunications, Electromagnetism and Electronics Systems Engineering). This institutional restructuration has been supported by regional innovation policies. Cisteme has been actively involved in the elaboration of collaborative projects and has also acted as a mediator between the research and industry sectors in the region.

We observe concomitantly the official creation of the Xlim lab in 2006 through the merger of four labs (including Ircom) that favors the acceptance and recognition of the lab as the spearhead of research in hyperfrequencies in Limousin. Its researchers were very active in the preparation of the application form of Elopsys to the CC policy, mobilizing their interpersonal relationships with companies and their high level of involvement in local structures. The cluster notably capitalized on the industrial collaborations built up by Xlim, while “the pre-projects of

the cluster were based on Xlim lab brainstorming on industrial requirements”, as the second head of Elopsys explained. Consequently, the organization of the laboratory around six research departments structured the cluster’s early technological specialization. The cluster founders - who were key individuals initially linked to Xlim, Cisteme, or companies within the cluster’s specialization - encouraged this fertile restructuration of the scientific ecosystem. This is the case of the current head of the cluster, and former head of Cisteme. In this respect, a researcher stated that, “in my mind I see no difference between Cisteme and Xlim. My contact is the same for both”, meaning that the individual level matters more than the organization one at the beginning.

The cluster emergence reaffirms the continuing role of indirect policies (*i.e.* the institutional restructuration of technologic and scientific structures) and the role of interpersonal relationships of the cluster founders. This has led to the reinforcement of the core competencies.

Legitimation from a local basis: evolution of policy rationales and reinforcement of the preexisting relationships (2006-2008)

Once clusters are officially set up, the national policy implements formal evaluation every three years to assess the performance of each competitiveness cluster and renew or not the label. Direct clusters policy has continued to structure heavily Elopsys development. Regarding the first policy rationale, the main challenge for the nascent cluster was to demonstrate the formal existence of a dynamic ecosystem of innovation. In this context, we observe a significant increase in the cluster’ size (Table 3): the number of projects was significantly high from the outset (30 projects labeled in 2006 and more than one hundred in the three first years), and the number of actors involved in the cluster grew rapidly (186 different participants in this period). The current head notes that “such a dynamic was only possible since the cluster was able to immediately translate intentions into real projects”. He also explains that “the Elopsys strategy was to legitimate the concrete existence of the cluster; by funding these first projects we proved

both its capacity to create collaborative projects thanks to local resources and partners, and the territorial impacts in terms of innovation and employment”. He finally adds that “at the end of the first three years of existence, the cluster reached a critical size allowing it to meet policy requirements”; Elopsys was indeed successfully qualified as a “project factory” and ranked among the 39 CCs (out of 71) that reached all the objectives of CC policy.

This growth is mainly based on the preexisting fertile science-industry relationships and the scientific core competencies detailed in the previous section. A researcher we interviewed confirms indeed “the first projects relied on a solid core of previous partners that knew each other prior to the official creation of the cluster”. Descriptive statistics reaffirm the projects labeled during this first phase were based on the pre-existing ecosystem: i) projects were focused on the microwave and photonics technologies (90% of total projects during the first years) that are the scientific core of the cluster; ii) they were mainly conducted by Elopsys members and local partners. Indeed, members are over-represented in participation volume compared to participant volume (Table 3): for example, local partners in innovation projects accounted for 25% of participants in 2006 and 43% of participation, meaning that they participated in many projects. The early life cycle of this cluster was marked by the very intensive participation of key earlier actors, among which the Xlim teams appear central. In addition, regarding the total number of projects, the six teams of the lab are over-represented since “researchers from Xlim systematically label their scientific projects”, as a project leader explained. The centrality scores throughout the period highlight the constant importance of the historical actors of Elopsys (i.e. continued presence of long-standing actors who renew previous partnerships). The key industrial actors (Table 4) reaffirm the crucial role of Xlim since they have a common laboratory with Xlim: Thales research chair, Alcatel Thales lab since 2004, Thales Alenia Space since 2006 and the CEA since 2014. The role of Xlim is also evidenced by the SNA with the isolated nodes (22 nodes) that partly constitute the creation of start-ups by

Xlim: 12 start-ups have been established by Xlim researchers within the studied period (and 11 have been located on ESTER park). While this result could be seen a priori as a cluster weakness considering that these nodes are isolated, but they are in reality closely linked to the scientific core of the CC through lab spin-offs. This comment highlights the ability of qualitative analysis to shed light on quantitative figures.

The localism appears also important in this cluster growth period regarding the funding sources (Table 3): one fifth of projects benefited from local funds in the first year (compared to 7% in the last one). The regional administration was strongly committed to this cluster policy in the search for local development. The nascent cluster turned this interventionist local policy into a winning strategy: the current head of the cluster considers that “the partnership was deliberately locally orientated at the beginning and aimed at promoting the territory and generating intellectual property”.

Finally, data indicates that the cluster has continued to be research-driven because of: i) the weight of scientific organizations in total participations (around 60% in the period), and ii) the predominance of project applications to the National Research Agency (ANR). This is partly explained by the central position of Xlim teams (as each of the six teams and Cisteme were involved in more than 10 projects).

4.3.Bifurcation

The openness tendency (2009-2011)

Once the local foundations of Elopsys had been laid, the cluster continued to grow during this period: the number of new projects doubled compared to the former period. The acceleration in the number of labeled projects, participants and ties in 2010/2011 led to a decrease in the renewal rate at the end of the period. In volume, the number of former partners surpassed that

of new ones since 2008. The renewal rate reaches a pick in 2009 (66%) and then decreases (Table 3). This openness did not prevent historical key actors from remaining central (Table 4). Explaining the formation of a project during this second period, a researcher notes that “among the nine partners, six new partners were added to the three historical members of Elopsys”. We consequently note a tendency towards an increase in the size of projects (from an average of 4 partners in phase 1 to an average of 5 partners in phase 2) and changes in terms of project funding: projects were initially based on local funds, and thereafter they were more frequently developed thanks to national and European funds and through bigger consortia (necessary to apply for European programs). This openness dynamic is observed statistically at various scales: institutional, geographical and technological.

We observe first an institutional openness tendency: the proportion of member-member connections decreased to 5% of total ties at the end of the period (Table 3), reducing the risk of institutional lock-in of the cluster. This trend is partly explained by a growing number of co-labelling practices in response to the policy incentives for inter-clustering. Following these national guidelines, 50% of projects were co-labeled at the end of 2011, with notably the PEC (Limousin), S2E2 (Centre) Images & Réseaux (Bretagne) and Minalogic (Rhône-Alpes). This strategy of openness was also engaged by some key players of the cluster such as the CTTC (technology transfer center in ceramics); in this regard, the head of the cluster mentioned that “it helped to bring the two competitive clusters of Limoges closer”.

Inter-clustering incentives led to the geographical openness of Elopsys. We observe the declining share of local funds counterbalanced by European projects, which were inexistent before (Table 3). Applications for European projects led to a higher share (25%) of international partners at the end of the second phase. Symmetrically, local actors become the smallest share of actors involved.

Finally, we note a technological openness: digital interfaces accounted for around 15% in the second phase while this technology was virtually absent in the first one. In 2009, against a backdrop of economies of scale, the region prompted Elopsys to integrate a new technology field initially owned by the region (e-design). This indirect cluster policy involving restructuration led to major repercussions on the network structure and its specialization: as explained by the head of the cluster, “this restructuration led to the formation of a fourth domain and therefore to a new growth trend in terms of both members and employment within the cluster”. In this context, a team from the Xlim laboratory working on signals, imaging and communication, became a central actor from 2009 onward (Table 4).

This openness tendency ran counter to local injunctions, demonstrating the role of the various levels of public policy. These different incentives created some tensions between the local institutions and the industrial actors involved in the cluster. More generally, this stage of development was mainly structured by cluster policies, direct and indirect, at the national and regional levels. To meet these new prerogatives, Elopsys relied on the initial key actors of the cluster (and their interpersonal relationships) but the new rationales lead to deeper changes (ie. expansion of the network both geographically and technologically) implying a first deviation from the initial trajectory.

We can notice that, in this growing period, the network appears increasingly integrated (Table 4): its development does not reduce the quality of information dissemination: i) the average degree has risen during the period, revealing that nodes are ever more connected to each other; ii) the density has naturally decreased as the network has grown; iii) the average distance and diameter are however stable over time, highlighting the integrated patterns of the network.

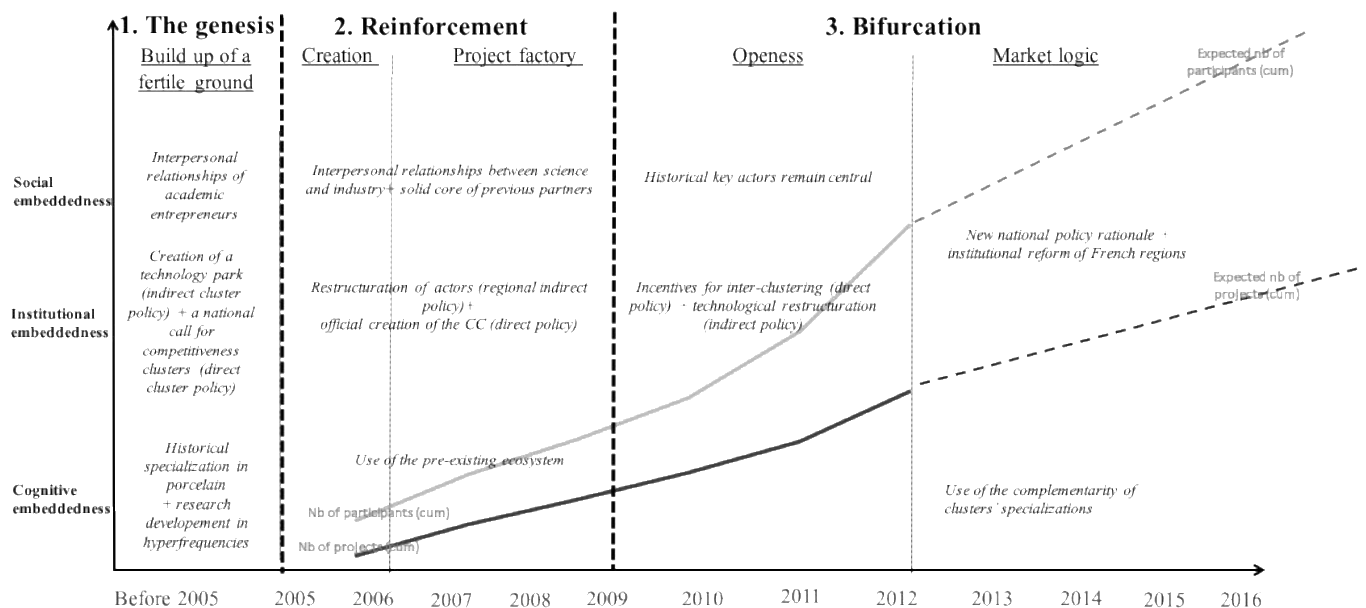
Market logic and new macroregional opportunities (2012-)

The last period is analyzed through qualitative data only since we do not have access to quantitative ones. According to managers' discourse, this period clearly appears to be characterized by the industrialization of the projects implemented, in coherence with phase 3 of the competitive cluster policy: following a national policy rationale to progress from a logic of technological development to a market rationale, an increase in industry-industry collaborations and applied research projects could be observed, as noted by the cluster's current head. Elopsys has had to shift from being a project factory to a product factory: "we are currently in a phase to secure the marketing of products that have been designed within the projects we have supported".

In addition, the organization of Elopsys is still impacted by the institutional reform of French regions (the number of regions decreased from 22 to 13). The Limousin region merged with two other regions (Aquitaine and Poitou-Charentes) to become Nouvelle-Aquitaine. "It will be an opportunity to broaden our scope of skills by working in collaboration with competitive clusters from the regions concerned. We are already in contact with them". Since the interviews, Elopsys has merged with the "Route des Lasers" CC located in Bordeaux, giving rise to Alpha-RLH. This process has led to structural changes for the future cluster's life cycle. This constitutes both the end of the independent trajectory of Elopsys and the beginning of a new CLC. In this context, the cluster trajectory, upstream to the fusion, could be considered as the genesis of the new cluster and as such determining for the future of Alpha-RLH. More precisely, this policy-driven reorganization will necessarily lead to a new openness trend and an increase in size. For the members, the complementarity of the two clusters' specializations could lead to skills improvements with greater opportunities in terms of innovation partnerships. Nevertheless, difficulties could exist regarding coordination within this bigger multi-site cluster, notably with new governance and geographic reorganization.

This last period reaffirms the existence of a bifurcation in the initial trajectory: Elopsys can no longer rely only on its scientific core competences and its initial network: the new institutional constraints and opportunities require to integrate in a larger network (ie. industrials and actors from Nouvelle-Aquitaine) than the one built over time. The following figure summarizes the whole life cycle of Elopsys and highlights its global trend.

Figure 2: CLC of Elopsys



5. Discussion and conclusion

The goal of the paper was to develop an enlarged, dynamic and comprehensive framework of the cluster life cycle focusing on the genesis period and its impact on the subsequent cluster trajectory. We have therefore developed a conceptual grid and a methodological strategy coherent with this goal (through the combination of various conceptual and methodological approaches). Based on the operationalization on a cluster case, we have been able to highlight the crucial role of the three levels of actions and their interactions to analyze the genesis period.

1) The nascent specialization of the local industry and more precisely the specific skills of

laboratories appeared crucial in the cluster emergence. 2) Nevertheless, this would not have been enough alone: preexisting policies (i.e. the technology park and regional support of the high-tech domain) facilitated the building of the cluster's early identity and the reinforcement of the nascent specialization. 3) The nascent specialization was also deeply based on preexisting relationships between academics and local industrials. The bases on which the cluster came into existence has a strong impact on its further evolution. The cluster trajectory continued to be driven by the initial policies and based on the nascent specialization and the preexisting relationships of founders. Nevertheless, the evolving of institutional rationales appears so structuring (cf. Ingstrup and Damgaard, 2013; Uyarra and Ramlogan, 2017) that they imply a bifurcation in the cluster initial trajectory. National direct cluster policies had a strong influence by giving recommendations at each evaluation step (incentives for the "project factory", inter-clustering, and "market logic"). Indirect ones had also a significant role (Carlsson, 2005; Prevezer, 2008; Flanagan *et al.*, 2011; Njos and Jakobsen, 2016) i) by heavily financing innovation projects, motivated by local benefits, ii) by constraining the restructuring of the cluster that led to technological openness; iii) through the current context of regional mergers. These results call for several comments. First of all, they raise new issues requiring a more comprehensive study of the cluster life cycle. It would be interesting to perform the cycle analysis for each technological domain. This is not contradictory to the above result showing the irrelevance of the product/technology life cycle as a driver of Elopsys; rather, it underscores the need for refinement through precise and separate analyses of each technology of the cluster and to deepen the links between the fields of technology. Last but not least, our results have policy implications. Until now, some authors regret that "little guidance is provided on the role of policies that are conducive to the formation of clusters, both what policies to promote and equally important what policy to avoid" (Feldman et al., 2006). Developing a comprehensive analysis combining various drivers allows to balance the role of path dependency created by

historical specialization or small events (on which anybody can have an impact) and the role of conscious direct policy initiatives. The dynamic perspective adopted shows how important are 1) the incorporation of a historical view to design effective policies (Perez, 2013) and 2) the adaptation of policies (Metcalf, 1994). It also indicates instruments do not work in isolation (Flanagan and Uyarra, 2016) and therefore no single policy is universally applicable: “no blueprints of cluster policies can be given simply because different contexts require different policies” (Van Klink and De Langen, 2001, p. 454).

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